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R. L. AMANS
LIGHT TRANSMITTING ELECTRODE INCLUDING N-TYPE
SEMICONDUCTIVE In_2O_3
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3,295,002

FIG. 1.

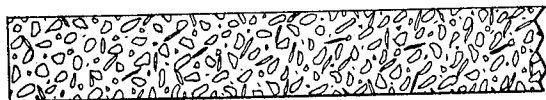


FIG. 2.

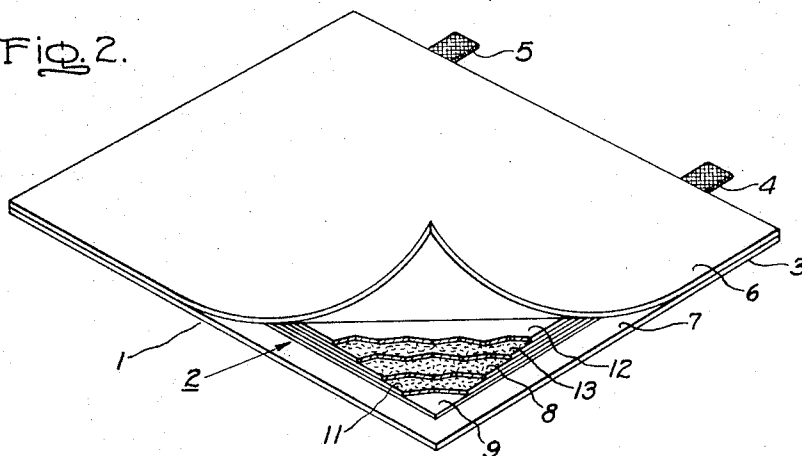
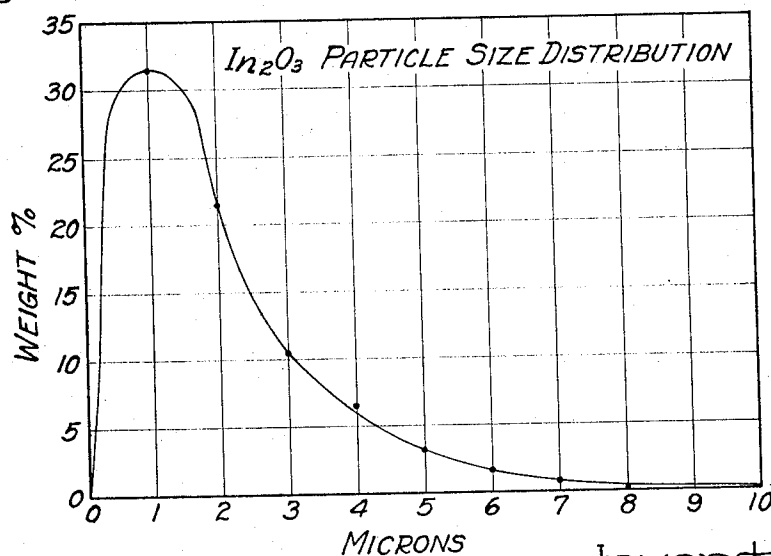


FIG. 3.



Inventor:
Robert L. Amans
by *Otto Fickel*
His Attorney

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LIGHT TRANSMITTING ELECTRODE INCLUDING N-TYPE SEMICONDUCTIVE In_2O_3

Robert L. Amans, Lyndhurst, Ohio, assignor to General Electric Company, a corporation of New York
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9 Claims. (Cl. 313-108)

The present invention relates to light transmitting electrical conductors, and more particularly to an improved light transmitting electrically conductive lacquer which can be used in flexible electroluminescent and electrically photosensitive devices. The invention also relates to improved flexible electroluminescent and electrically photosensitive devices incorporating the lacquers.

Basically, electroluminescent and electrically photosensitive devices can be grouped into two classes: ceramic and organic. The organic devices possess an advantage in being somewhat flexible and much tougher and less fragile than the ceramic devices. In either type of device it is necessary to have at least one electrode which is sufficiently light transmitting to make the device practical. A useful electrode must also be sufficiently electrically conductive to allow the construction of practical devices. Obviously, the larger the light transmitting surface, the greater is the conductivity required in the electrode. It is common practice to use strip electrodes of conductors such as silver paint along the edges of larger devices such as lamps to enhance the spread of electrical field across the surface of the lamp. However, it is generally desirable to avoid such light impervious conductors on the portion of the device which produces or receives light.

By electrically photosensitive device is meant those devices such as photoconductive and photovoltaic devices which respond to light and variations in light by changes in their electrical characteristics. Electroluminescent devices include, among others, lamps, display devices and circuit elements.

In the manufacture of some electroluminescent devices, such as display devices, it is desirable to be able to create light in varied and specific patterns. This can be done either by utilizing a patterned back (non-light-transmitting) electrode or by using a patterned front (light-transmitting) electrode. It is further advantageous to be able to place a front electrode on an electroluminescent device in a discontinuous manner. It is common practice to form several layers of an electroluminescent device by semi-continuous techniques as by doctor-blade coating of an insulating layer on aluminum sheet as the sheet is unrolled from a coil, and then, after drying the insulating layer, coating a phosphor layer on top of it before rewinding the sheet onto a take-up coil. Lamps are then cut to size from the sheet as needed. Generally, the front electrode subsequently is placed on a lamp subassembly which has been cut to size, with the electrode of a size smaller than the lamp so that it does not reach the edges. This prevents edge arcing between front and back electrodes. By use of a silk screen process, or by similar means, the front electrode can be formed directly on the semi-continuous coated aluminum sheet after applying and drying the phosphor layer. It is therefore desirable to utilize a lacquer which possesses rheological and other properties suitable for silk screening in the production of the front electrode for an electroluminescent lamp. The other advantages of the silk screen process are apparent to those skilled in the art. For instance, patterned front electrodes can be applied in a semi-continuous production run. In fact, patterned front electrodes are difficult to produce by any method other than silk screening.

In addition, silk-screening techniques are quite useful in the mass-production of miniature electroluminescent lamps and photoconductors for use as circuit elements.

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Many such elements can be produced at once by silk-screening small front electrodes on a sheet sub-assembly, and then using a die to cut the sheet into separate elements.

5 It is an object of the present invention to provide a lacquer which can be used to form improved light transmitting electrical conductors.

It is a further object to provide such electrodes having high conductivity and light transmittance, as well as adaptability to silk-screening techniques.

10 Another object is to provide improved electroluminescent and electrically photosensitive devices utilizing such electrodes.

Other and further objects and advantages will become apparent from the following description.

In the drawing:

FIG. 1 is a schematic illustration of the cross-section of an electrode made according to the invention.

20 FIG. 2 is a pictorial view of a flexible electroluminescent lamp incorporating an electrode of the invention, with the various constituent layers thereof delaminated or peeled open at one corner to show the internal construction of the lamp which is partially broken away in layers.

25 FIG. 3 is a graph of a particle size distribution curve for one batch of indium oxide used in the investigation of the present invention.

Briefly stated, the present invention, in one form, consists of a light transmitting electrically conductive lacquer of ethyl hydroxyethyl cellulose containing from about 30% to about 70% or preferably 40-50% by volume of indium oxide (In_2O_3) which is present as fine particles, generally in the size range of less than 10 microns diameter. In a preferred form, the indium oxide is utilized in an oxygen-defect or anion-defect condition; such material is an n-type semiconductor and produces a lacquer having substantially greater conductivity than is available from stoichiometric indium oxide. Electroluminescent lamps incorporating such lacquer have shown an unexpected, and as yet unexplained, improvement in maintenance and brightness.

Referring now to the drawings:

45 FIG. 1 illustrates a lacquer layer containing particulate indium oxide in its preferred form. The plate-like shape of the particles shown enhances particle-to-particle contact of the conductive shape, thereby improving electrical conductivity. The matrix is a plastic material consisting essentially of ethyl hydroxyethyl cellulose.

50 FIG. 2 shows an electroluminescent lamp which is more fully described in the co-pending application of Jaffe et al. hereinafter referred to. The lamp 1 comprises a plastic encapsulation 3 consisting of a front layer 6 and a back layer 7 laminated together to contain the cell portion 2. Electrical leads 4, 5 allow energization of the lamp. In this instance, the cell portion comprises a back electrode 9 of aluminum, a barrier layer 11, a phosphor layer 8, a front electrode 13, and a sheet of hydrophobic material 12 to absorb water vapor. The front electrode 13 may comprise the lacquer of the present invention.

55 Ethyl hydroxyethyl cellulose, sometimes known as cellulose ether, is available commercially from the Hercules Powder Company of Wilmington, Delaware, under the designation of EHEC. This material can be described as a cellulose structure in which varying numbers of the hydrogen atoms attached to the basic cellulose ring have been replaced by ethyl or hydroxyethyl groups. It is understood in the art that materials having somewhat different properties can be obtained by replacement of varying numbers of hydrogen atoms with varying proportions of ethyl, hydroxyethyl, and hydroxy groups. The degree and proportions of reaction are commercially

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specified by stating the viscosity of the material. EHEC is commercially available in viscosities of 10 to 35 centipoises and 125 to 250 centipoises. For the purposes described herein, the degree and proportion of reaction and therefore the viscosity of the material is not controlling since wide variations can be compensated for by differing uses of solvents.

When used in a silk screen process, the viscosity of the lacquer determines the thickness and other characteristics of the film deposited, but the viscosity of the lacquer is quite strongly dependent on both volume loading of hard dispersed particles and the solvent techniques used. This is apparent from the fact that some of the examples discussed below utilized lacquers having a viscosity of 100 poises which is from 400 to 1000 times as great as the viscosity of the EHEC raw material.

Ethyl hydroxyethyl cellulose has been used commercially in the paint industry for silk-screening purposes. However, so far as the applicant is aware, previous uses of ethyl hydroxyethyl cellulose have given no indication of its electrical properties, its suitability for producing light transmitting electrically conductive lacquers, its ability to be cured at high temperatures, or any of several other factors important in the commercial production of electroluminescent and electrically photosensitive devices.

In copending application, Serial No. 189,095 filed April 20, 1962—Mary I. Jaffe et al., assigned to the same assignee as the present invention, indium oxide is disclosed as being a suitable conductive phase for use in making conductive lacquers for light-transmitting electrodes of electroluminescent devices. The term lacquer as used in this art is directed to an organic matrix material containing a dispersed, inorganic, crystalline second phase. The disclosure of that application, however, does not indicate that the indium oxide should be heat treated to create an oxygen (anion) deficient lattice structure, nor does it provide a lacquer having the same type of versatility and adaptability as the lacquer herein disclosed.

A number of variables were tested and compared in a research program leading to the present invention, and several of them will be described herein by way of example. These examples are meant to be illustrative of the invention and not limitative thereof.

In the above-identified application of Jaffe et al., it is stated that the inherent photoconductivity of commercial grade indium oxide will result in nonuniformity or variation in brightness of lamps made using such oxide in the light-transmitting conductive electrode, said variations depending on the differences in the surrounding light conditions to which the lamps have been exposed immediately prior to their operation. It is stated that this photoconductivity can be overcome by firing the indium oxide powder in air for a period of around one hour at an elevated temperature of about 1000° C. before its incorporation into the conductive lacquer.

Although it is still believed that similar heat treatments at temperatures preferably in the range of 850–1000° C. are desirable for decreasing photoconductivity, I have now found that other mechanisms are also involved and should preferably be taken into account in the production of indium oxide for use in light-transmitting electrodes. Prior to firing, the indium oxide used has been found to contain some indium nitrate which could inhibit dark conductivity. After firing, the nitrate was converted to the oxide, and the dark conductivity increased appreciably.

It is believed that this conductivity increase is due to the creation of an anion (oxygen) deficient crystal structure in which electrons replace the missing anions. Such a structure displays electron conductivity, and such materials are commonly called n-type semi-conductors. In addition to the foregoing procedure, n-type semi-conductivity can be induced in indium oxide by doping with

metals of higher valency such as tin, niobium and several others as substitutional impurities, or by partial replacement of the anion (oxygen) by halogens, or by both means. These methods produce anion deficient structures which have n-type semi-conductive properties and are well known in the art. However, most metal oxides of white or light colored character having variable valencies and which can be made conductive in the dry state do not exhibit any appreciable conductivity when dispersed in an essentially non-conducting organic plastic or resin matrix. I have discovered that the combination of anion deficient indium oxide with ethyl hydroxyethyl cellulose as herein disclosed possesses unusual and unexpected properties useful in light-transmitting electrical conductors.

In testing my belief concerning the semi-conductive contribution to the properties of these lacquers, indium oxide has been produced by ignition of indium hydroxide, resulting in a more stoichiometric indium oxide. This material, when incorporated into a lacquer in a manner comparable to that used with the previous material, was found to have conductivity on the order of ten times less than that of indium oxide produced from indium nitrate. Therefore, it appears that care must be taken in the selection of raw materials and their processing and firing schedules to produce an indium oxide having appreciable semi-conductivity for optimum results.

Prior to firing, the indium oxide is milled to break up agglomerates, generally by the methods disclosed by Jaffe et al. In using an indium oxide—ethyl hydroxyethyl cellulose lacquer, the indium oxide can be milled in solvents compatible with the resin so that drying is not necessary before mixing of the milled indium oxide with the resin.

In attempting to optimize the manufacturing performance of conductive lacquers used in electroluminescent lamps, several alternatives for the plastics formerly used were investigated. Polar groups such as hydroxyls are desirable for wetting of indium oxide to avoid flocculation, thereby making ethyl hydroxyethyl cellulose more desirable in the present application than non-polar materials such as polystyrene. Jaffe et al. have disclosed the use of cyanoethyl cellulose plasticized with cyanoethyl phthalate, cyanoethyl starch plasticized with cyanoethyl phthalate or cyanoethyl sucrose, and other plastic compositions. In the present investigations, a primary objective was to discover materials that would handle more easily and be more amenable to production line techniques such as conventional silk screening while also having improved light production and electrical properties. Several plastics containing polar groups such as hydroxyls, amides and carboxyls were studied. These included hydroxyethyl cellulose, cellulose acetate butyrate, Zytel 61 (a nylon resin produced by E. I. du Pont de Nemours and Co.), Versamid 940 (trademark for a polyamide produced by the General Mills Company), carboxymethyl cellulose, and ethyl hydroxyethyl cellulose.

Both hydroxyethyl cellulose and carboxymethyl cellulose are water-soluble. This causes two undesirable effects in the present applications. Water is known to be a primary cause of decreased lamp maintenance (decrease in light output during use); furthermore, water-soluble lacquers are generally considered to evaporate too rapidly for optimum silk-screening operations. On the other hand, ethyl hydroxyethyl cellulose is soluble in mineral spirits which do not attack the plastic systems normally used for phosphor layer matrices in electroluminescent lamps, such as cyanoethyl cellulose plasticized with cyanoethyl phthalate.

In these applications, Versamid 940 may be useful in varying amounts as an adhesive binder, but, when used as the primary matrix, it is subject to yellowing due to thermal degradation during curing of the lamp and during use unless properly stabilized by methods known in the art. Ethyl hydroxyethyl cellulose is not affected by thermal degradation during the normal curing cycle of 230° C. for

30 seconds. Versamid 940 does not seem to materially affect the basic and novel combined electrical and optical properties of the lacquers of the present invention when used as an adhesion promoting additive. Versamid 940 added in amounts of 10–20% by volume aids in preventing delamination of the lamps. Also, Versamid 940 is compatible with ethyl hydroxyethyl cellulose and mineral spirits, but its rheological properties make it difficult to silk screen when used in percentages that are too large. Versamid 940 is a thermoplastic polymer with a molecular weight ranging from 3,000 to 6,500 and an ASTM ball and ring softening point from 105 to 115° C. It is prepared by the condensation of polymerized unsaturated fatty acids such as dilinoleic acid with aliphatic amines such as ethylene diamine. Other additives can be also used to enhance other properties of the lacquers without materially affecting the basic and novel properties of the invention.

It has been determined that alcohol soluble nylon-type materials in the present application lead to unsatisfactory lamp maintenance and are not readily applied by silk-screening techniques. The low maintenance is due, in part, to the use of alcohol solvents with the nylon. Alcohol is miscible with water, and the solvent release of such systems is relatively poor.

As compared with cyanoethyl cellulose and cyanoethyl phthalate, ethyl hydroxyethyl cellulose is far less expensive and has advantages in certain applications and with certain manufacturing techniques due to its solubility in non-polar solvents, thereby avoiding wetting or attack of the phosphor layer during application. Ethyl hydroxyethyl cellulose is also more thermoplastic than cyanoethyl cellulose, thereby allowing the manufacturer more freedom in specifying laminating techniques. The silk-screening properties of ethyl hydroxyethyl cellulose are also better than those of cyanoethyl cellulose. Furthermore, in an unlit lamp, ethyl hydroxyethyl cellulose lacquers give a sometimes more desirable cream-color as compared to the bluish-gray color of a cyanoethyl cellulose lamp.

In contrast to the presumptions implied in the design of lamps using cyanoethyl cellulose as a matrix material, it has been discovered that an ethyl hydroxyethyl cellulose plastic matrix having a lower rather than higher dielectric constant produces lacquers with indium oxide having a relatively high electrical conductivity. The electrical conductivity mechanism in ethyl hydroxyethyl cellulose is not completely understood. From normal considerations, the plastic should be a good insulator; however, there may be substantial factors of semi-conductivity present in the material. Alternatively, it may be that the lacquer as used has sufficient particle-to-particle contact between indium oxide grains to provide the high conductivity. Indium oxide milled as described by Jaffe et al. and fired at about 950° C. for a half-hour in air often has an acicular structure or a plate-like structure, thereby enhancing particle-to-particle contact, and electrical conductivity of the lacquer. When the indium oxide particles are in a platelet form, the capacitance of the lacquer may be higher than otherwise due to a higher ratio of surface area to volume.

Since the present invention is primarily an improvement on the light-transmitting conductive lacquers described by Jaffe et al., and used in flexible electroluminescent lamps also described by Jaffe et al., the details of that application will not be repeated here. The indium oxide used in the present invention is basically that described by Jaffe et al. with the exception that it should preferably come from sources such as nitrates so that after firing and when ready to be incorporated into a lamp the material is an n-type semiconductor.

Ethyl hydroxyethyl cellulose is mixed with a sufficient quantity of solvent consisting of 92% mineral spirits (petroleum hydrocarbon solvent, non-polar, such as kerosene or painter's naphtha) and about 8% isopropyl alcohol to provide a clear solution. Forty to fifty percent

by volume In_2O_3 is then mixed into the ethyl hydroxyethyl cellulose solution. The volume percentages are determined on the basis of actual volume of the materials rather than bulk volume. The significance of this is that the volume of indium oxide is determined by dividing its weight by its actual density, rather than by measuring bulk density or bulk volume of the material in powder form. The preferred particle size distribution is substantially all below about 10 microns diameter. The best results are now considered to be achieved with the mode (peak) between about 0.3 and 3.0 microns diameter. FIG. 3 is a distribution plot based on weight percent at particular sizes of one lot of indium oxide powder used for the present investigation. The mode of the curve is at about one micron diameter and its median is at about 2.2 microns diameter. In a size distribution displaying more than one mode, it is preferred that at least the major mode be substantially within the limits indicated.

Preferably, the mixture is made by beginning with the solvent in a mixing apparatus such as a blender which is in motion and adding a sufficient quantity of dry ethyl hydroxyethyl cellulose. After the dry resin is completely dissolved, the indium oxide is slowly added for blending. In case the suspension becomes too viscous, additional solvent may be added at any time. To complete the mixing, a paint roller mill can be used to disperse all large agglomerates. After milling, additional solvent may be added to obtain the desired viscosity. The thickness of the applied lacquer layer is a function of viscosity for different methods of application. For silk screening, an exemplary viscosity is about 120 poises; for doctor-blade coating, an exemplary viscosity is about 200 poises.

Using conventional silk-screening techniques (the screen may be of a material other than silk), the lacquer may be applied in intricate patterns, in simple square lamp shapes, or in any other manner desired. As is well known in the art, patterns can be produced on silk screens by mechanical or photographic techniques. The size of mesh in combination with the lacquer viscosity largely determines the dry thickness of the lacquer layer applied. For example, using an 8XX silk screen (openings of about 0.0076 inch square) and a lacquer made from low viscosity (20 to 35 centipoises) ethyl hydroxyethyl cellulose, the lacquer viscosity being about 100 poises, electrodes have been made having a dry thickness of about 7 microns. For the preferred results, the lacquer should be applied to the screen from the squeeze bottle in an amount sufficient to allow only one or two pulls of the squeegee. In a test run, 50 lamps were screened in succession by the above techniques, and it was found that the thickness variation was only ± 0.3 micron for various applications. The lacquer coatings can be produced to a dry thickness of 5, 10, or 15 microns or to any other desired thickness. Also, it is not necessary to apply the lacquer directly to the phosphor layer of a lamp. The lacquer can be coated on a sheet of nylon 66 or nylon 6, such as that known as "Caplene" which is then used to produce a lamp as described by Jaffe et al.

The thermoplastic nature of ethyl hydroxyethyl cellulose provides for good adherence of the conductive lacquer to the phosphor layer during lamination of the lamp under hydrostatic pressure of about 250–300 p.s.i. at about 230° C. for about 30 seconds, even though there is little or no wetting of the phosphor layer by the lacquer. Versamid 940 aids in further improving adherence. Such wetting can be deleterious to lamp properties. The laminating of the lamp may be performed in the manner and by the use of a hydrostatic laminating press such as described in Patent 2,945,976—Fridrich et al., assigned to the assignee of the present invention.

To further point out the unexpected and unobvious benefits of the present invention, the discussion of interaction of the electrical and optical properties of In_2O_3 -ethyl hydroxyethyl cellulose electrodes as compared to electrodes previously used is appropriate. Although the

optical transmission of electrodes of the invention is substantially lower than that of some previously known electrodes, the electrical properties of the electrodes of the invention are greatly enough improved over those previously known electrodes that the brightnesses of otherwise equivalent lamps are much greater in lamps using In_2O_3 -ethyl hydroxyethyl cellulose electrodes. In electroluminescent devices, an overall gain in the production of light is, of course, the desired goal, provided other properties such as maintenance are not deleteriously effected. The maintenance of lamps made using the present invention is as good as or better than that of lamps using previously known electrodes. In electrically photosensitive devices a loss in optical transmission can generally be accommodated by enhanced conductivity of the film or layer. A more conductive film can be used at a lower thickness than can a less conductive film, thereby compensating for the transmission per unit thickness and perhaps resulting in a better overall performance. Similar considerations apply in the use of light transmitting electrodes for other purposes such as for heating the windshields of aircraft to avoid the formation of ice.

The conductive glass paper—conductivity aid electrode described by Jaffe et al., can be used for comparison with electrodes made according to the present invention. As a 10 micron film thickness, and after having been processed at the temperatures and pressures used in a commercial laminating operation, the Jaffe et al. electrode had a transmission in a green electroluminescent lamp of about 79% of the light produced. Similar measurements were made on lamps containing the electrode of the present invention in which the In_2O_3 was provided in three size ranges: less than 1 micron diameter, 1–3 microns diameter, and 3–6 microns diameter. The percentages of light transmission for these three electrodes at a corresponding 10 micron film thickness were, respectively, 56%, 61% and 64%. Thus, it is seen that the light transmission of lacquers of the invention average about 18% total below that of previously known electrodes. However, the brightness of lamps made with the electrodes of the invention, is about 15% higher than that made with such previously known electrodes. This large gain in total brightness is principally caused by improvements in electrical properties perhaps including capacitance as well as resistance in electrodes made according to the present invention. It is seen that ethyl hydroxyethyl cellulose electrodes made with In_2O_3 particles having a larger diameter have greater light transmission than those made with smaller particles; on the other hand, the larger size particles in the lacquer have been found to result in lower conductivity than the smaller size particles in the lacquer.

As an example of the conductance of lacquers of the present invention, 50–50 (volume percent) lacquers, laminated in lamp construction to thicknesses of 10 microns and having particle size ranges of 3–6 microns, 1–3 microns, and less than 1 micron diameter, were measured for resistance. The resistances in ohms per square were respectively, about 2130, 1180, and 725. Equivalent prior electrodes had a resistance of about 1650 ohms per square. The resistance measurement of ohms per square is constant in conductors in the form of sheet of uniform thickness regardless of the dimension of a side of the square.

The superiority of brightness maintenance of ethyl hydroxyethyl cellulose— In_2O_3 electrodes over conductive glass paper—conductivity aid electrodes is illustrated by tests which have shown samples of the former to be about 0.8 footlambert brighter than the latter after 30 hours of operation, and the difference in brightness after 850 hours of operation to be about one footlambert, with the electrodes of the present invention still being the brighter.

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

1. A light transmitting electrical conductor comprising

lacquer consisting essentially of a dispersion of finely divided In_2O_3 in ethyl hydroxyethyl cellulose, said In_2O_3 being in an n-type semi-conductive condition.

2. A light transmitting electrical conductor comprising lacquer consisting essentially of a dispersion of finely divided In_2O_3 in ethyl hydroxyethyl cellulose, said In_2O_3 being in an amount of about 40 to 50% by volume of total of said lacquer, said In_2O_3 being in an n-type semi-conductive condition, and said In_2O_3 having its particle size distribution mode between about 0.3 micron and about 3.0 microns diameter.

3. An electroluminescent device comprising a phosphor and at least one light transmitting electrode, said electrode consisting essentially of In_2O_3 dispersed in ethyl hydroxyethyl cellulose, said In_2O_3 being in an n-type semi-conductive condition.

4. An electroluminescent device comprising a phosphor and at least one light transmitting electrode, said electrode consisting essentially of In_2O_3 substantially uniformly dispersed in ethyl hydroxyethyl cellulose to form a lacquer, the proportion of said In_2O_3 being from about 40% to 50% by volume of said lacquer, said In_2O_3 having its particle size distribution mode between about 0.3 micron and 3.0 microns diameter, and said In_2O_3 being in an n-type semi-conductive condition.

5. An electrically photosensitive device comprising an electrically photosensitive material and at least one light transmitting electrode, said electrode consisting essentially of In_2O_3 dispersed in ethyl hydroxyethyl cellulose, said In_2O_3 being in an n-type semi-conductive condition.

6. An electrically photosensitive device comprising an electrically photosensitive material and at least one light transmitting electrode, said electrode consisting essentially of In_2O_3 substantially uniformly dispersed in ethyl hydroxyethyl cellulose to form a lacquer, the proportion of said In_2O_3 being from about 40% to 50% by volume of said lacquer, said In_2O_3 having its particle size distribution mode between about 0.3 micron and 3.0 microns diameter, and said In_2O_3 being in an n-type semi-conductive condition.

7. A light transmitting electrical conductor comprising lacquer consisting essentially of a dispersion of finely divided In_2O_3 in ethyl hydroxyethyl cellulose, said In_2O_3 being in an n-type semi-conductive condition, said In_2O_3 having substantially all of its particle size distribution at less than about 10 microns diameter, and said In_2O_3 being in an amount of about 30 to 70% by volume of said lacquer.

8. An electroluminescent device comprising a phosphor and at least one light transmitting electrode, said electrode consisting essentially of In_2O_3 dispersed in ethyl hydroxyethyl cellulose to form a lacquer, said In_2O_3 being in an n-type semi-conductive condition, said In_2O_3 having substantially all of its particle size distribution at less than about 10 microns diameter, and the proportion of said In_2O_3 being from about 30% to about 70% by volume of said lacquer.

9. An electrically photosensitive device comprising an electrically photosensitive material and at least one light transmitting electrode, said electrode consisting essentially of In_2O_3 dispersed in ethyl hydroxyethyl cellulose to form a lacquer, said In_2O_3 being in an n-type semi-conductive condition, said In_2O_3 having substantially all of its particle size distribution at less than about 10 microns diameter, and the proportion of said In_2O_3 being from about 30% to about 70% by volume of said lacquer.

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JAMES W. LAWRENCE, *Primary Examiner.*

R. JUDD, *Assistant Examiner.*