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METHOD FOR MAKING AN ELECTROLUMINESCENT DEVICE

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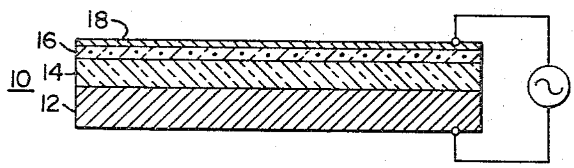

Fig. 1.

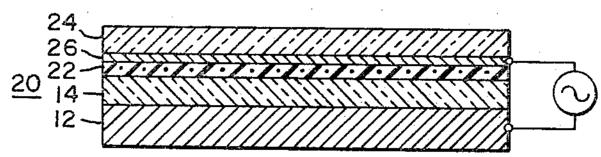

Fig. 2.

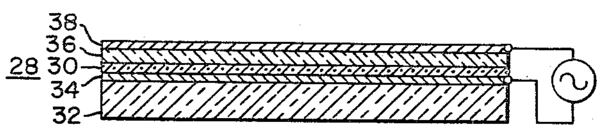

Fig. 3.

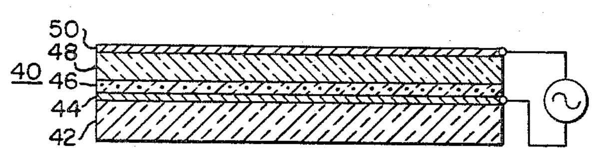

Fig. 4.

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METHOD FOR MAKING AN ELECTROLUMINESCENT DEVICE

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This invention relates to electroluminescent devices and method and, more particularly, to an electroluminescent device which displays improved performance characteristics and a method for fabricating such a device.

Electroluminescent devices are described in some detail by Destriau in London, Edinburgh and Dublin Philosophical Magazine, Series 7, volume 38, No. 285, pages 700–737 (October 1947). Such devices normally comprise a layer of finely divided electroluminescent phosphor embedded in an organic or inorganic dielectric material, which phosphor-dielectric layer is sandwiched between two electrode layers, at least one of which is light transmitting. The phosphor responds to an energizing alternating electric field applied across the device electrodes to generate light.

In the usual case, the more intense the electric field which is applied across the phosphor, the greater the light output. In order to increase the light output, it has been known to incorporate a separate layer of high dielectric material between the device electrodes, which separate layer has only a very small electric field drop thereacross. With such a construction, the voltage which can be applied across the device electrodes can be increased greatly, since the additional high dielectric layer provides considerable protection against electric breakdown between the device electrodes. High dielectric materials such as barium titanate have been considered for use as a separate layer in an electroluminescent device, but have not been used extensively since it is difficult to fabricate such materials into continuous layers.

It is the general object of this invention to provide a method for fabricating an electroluminescent device which has improved performance characteristics.

It is another object to provide an electroluminescent device which has improved performance characteristics.

The aforesaid objects of the invention, and other objects which will become apparent as the description proceeds, are achieved by forming two separate, contiguous layers, one of which layers comprises electroluminescent phosphor and the other of which layers principally comprises barium titanate which has been deposited by flame spraying. These two contiguous layers are placed between spaced electrodes, with the electrode positioned next to the phosphor layer being light transmitting, in order to pass the light which the device generates when operated. There is also provided an improved electroluminescent device in which a separate high dielectric constant layer, which principally comprises barium titanate, has been deposited by flame spraying.

For a better understanding of the invention, reference should be had to the accompanying drawings wherein:

FIGURE 1 is a sectional elevation of one embodiment of an electroluminescent device fabricated in accordance with the present invention, wherein a layer of flame-sprayed barium titanate is coated over a metallic substrate, with the phosphor coated over the barium titanate;

FIG. 2 is a sectional elevation illustrating an alternative embodiment of the device as shown in FIG. 1, wherein the phosphor-dielectric layer and light-transmitting electrode layer are modified;

FIG. 3 is a sectional elevational view of an electroluminescent device which incorporates a thin, continuous film of phosphor and a layer of flame-sprayed barium titanate thereover; and

FIG. 4 is a sectional elevational view of an electroluminescent device wherein a layer of flame-sprayed barium titanate is included over the phosphor-dielectric layer, with the electrode which is positioned next to the barium titanate layer being vacuum deposited.

With specific reference to the form of the invention illustrated in the drawings, the device embodiment 10, as shown in FIG. 1, comprises a metallic substrate 12 which is formed of enameling iron and has a thickness of approximately 0.1 inch, for example. Over the substrate 12 is carried a continuous layer of barium titanate 14 which has a thickness of approximately 0.1 mm. A layer 16 comprising finely divided electroluminescent phosphor embedded in glass is positioned over the barium titanate layer 14 and a light-transmitting electrode layer 18 is formed over the phosphor-dielectric layer 16.

In fabricating the device 10, as shown in FIG. 1, the enameling iron substrate 12 desirably is slightly roughened on the side which is to be coated and the layer 14 of barium titanate is flame sprayed over the roughened surface to the indicated thickness of 0.1 mm. In conducting such flame spraying, commercial types of flame spray guns have been found to be quite suitable and the usual oxy-hydrogen flames can be used. There is nothing particularly critical about the thickness of the formed barium titanate layer 14, particularly since the dielectric constant of this formed layer is extremely high, which in turn minimizes electric field drop which occurs thereacross, even when the layer 14 is relatively thick. Of course the layer 14 should be free from voids or discontinuities.

The phosphor-glass layer 16 is formed by mixing a frit of finely divided glass, which has a relatively low softening temperature, with finely divided electroluminescent phosphor such as copper-activated zinc sulfide, with the weight ratio of phosphor to glass being 1:2, for example. The mixed phosphor and finely divided glass are placed on the formed barium titanate layer 14 and heated to the softening temperature of the glass, so that a continuous layer 16 of glass having finely divided phosphor embedded therein is formed on the layer 14. As an example, the layer 16 has a thickness of two mils. This thickness is not critical and can be varied considerably. A light-transmitting electrode layer 18, of tin oxide for example, is then formed over the layer 16. Such tin oxide electrode layers are well known in the electroluminescent art and other materials such as copper iodide, for example, can be substituted therefor.

The device embodiment 20, as shown in FIG. 2, is generally similar to the device embodiment 10 of FIG. 1, except that the phosphor is embedded in a plastic dielectric material, such as a copolymer of polyvinyl chloride and polyvinyl acetate. In forming the phosphor-plastic dielectric layer 22, a solvent is used to dissolve the plastic and the phosphor suspended as a slurry in the dissolved plastic. The slurry is sprayed onto the barium titanate layer 14, and the solvent evaporated to leave the residual phosphor-dielectric layer 22. Over the layer 22 is pressed a plate of glass 24 which is coated on one side with a layer of light-transmitting, electrically conducting tin oxide 26.

In the device embodiment 28, as shown in FIG. 3, a thin, continuous layer of electroluminescent phosphor 30 is deposited onto a glass substrate 32 which has been previously coated with a light-transmitting, tin oxide electrode layer 34. Such a thin film of phosphor is generally described in U.S. Patent No. 3,044,902, dated July 17, 1962. Over the phosphor film layer 30 is formed a flame-sprayed layer of barium titanate **36**, which titanate layer can have a thickness of 0.15 mm. for example. Over the titanate layer **36** is vacuum deposited an aluminum electrode layer **38**. The advantage of such a construction is that most of the applied field is actually applied across the phosphor film **30**, which need only have a thickness in the order of four microns. As a result, the device operates with a high degree of brightness and is also protected against electrical breakdown across the electrodes by the barium titanate layer **36**.

In the device embodiment **40**, as shown in FIG. 4, the glass substrate **42**, which previously is coated with a layer **44** of light-transmitting and electrically conducting tin oxide, has coated thereover a layer **46** of glass which has finely divided electroluminescent phosphor embedded therein. Over the layer **46** is flame sprayed a barium titanate layer **48**, as in the previous examples. To complete the device, an additional aluminum electrode layer **50** is vacuum deposited onto the layer **44**.

In all of the foregoing device embodiments, electrical connection is made to the spaced electrodes so that the energizing alternating potential can be applied across the spaced electrodes. Various types of connections for effecting contact between the lead-in conductors and the electrodes are well-known.

Any of the devices as described hereinbefore can be protected against ingress of moisture, to insure proper maintenance of initial light output, by encapsulating the devices with a moisture-impervious material. In addition, the flame sprayed barium titanate layers as used in these devices can be modified by incorporation of other materials to replace a part of the barium titanate. For example, a mixture of 25% strontium titanate and 75% barium titanate can be flame sprayed in a manner similar to that described for the barium titanate.

Under operating conditions, devices fabricated in accordance with the present invention display a high degree of brightness and are protected against electrical breakdown across the device electrodes.

It will be recognized that the objects of the invention

have been achieved by providing an electroluminescent device which has improved operating characteristics and a method for making an electroluminescent device which has improved operating characteristics.

While best embodiments have been illustrated and described hereinbefore, it is to be particularly understood that the invention is not limited thereto or thereby.

What is claimed is:

1. In a method of manufacturing an electroluminescent device which incorporates as a component thereof a separate layer principally comprising barium titanate carried on and adhered to a rigid substrate, the improvement which comprises, flame spraying barium titanate as a continuous layer of predetermined thickness onto said substrate.

2. The method as specified in claim **1**, wherein said substrate comprises an electroluminescent phosphor layer carried on an additional supporting member, and said barium titanate layer is applied over and adhered to said phosphor layer.

3. The method as specified in claim **1**, wherein said substrate is a metallic member which serves as one electrode for said device.

4. The method as specified in claim **3**, wherein after said barium titanate layer is formed, a layer comprising electroluminescent phosphor is applied thereover and adhered thereto, and thereafter an additional electrode layer is applied over and adhered to said phosphor layer.

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