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PROCESS FOR MANUFACTURING AN ELECTROLUMINESCENT DEVICE

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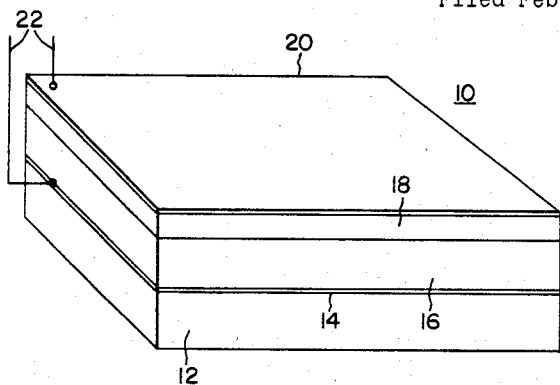


FIG. 1.

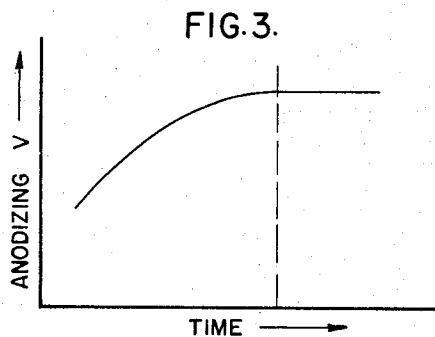


FIG. 3.

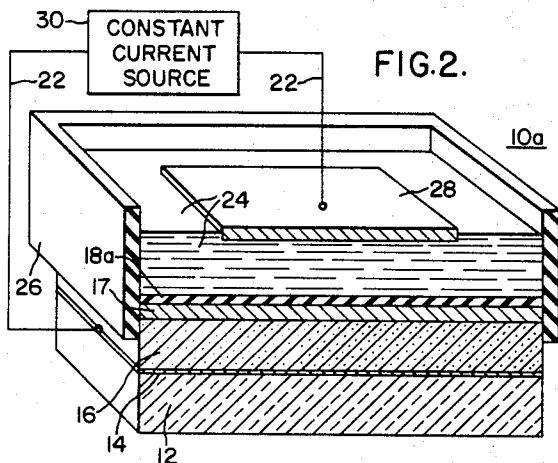


FIG. 2.

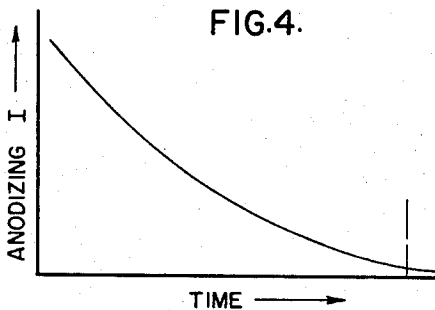


FIG. 4.

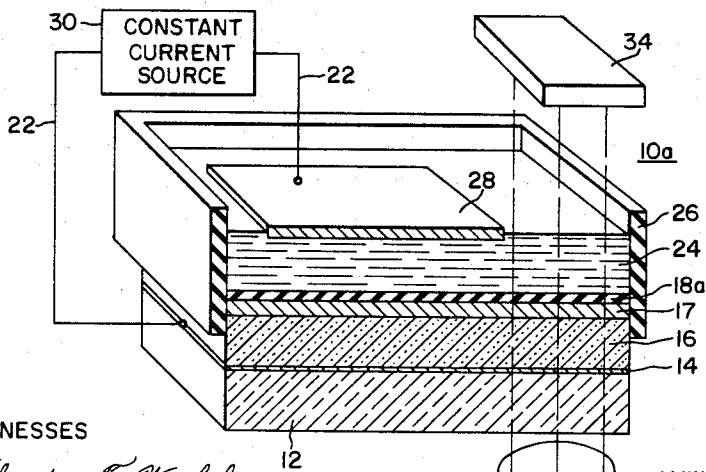


FIG. 5.

WITNESSES

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PROCESS FOR MANUFACTURING AN ELECTROLUMINESCENT DEVICE

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5 Claims. (Cl. 204—38)

This invention relates, generally, to electroluminescent devices and, more particularly, to a process for manufacturing such devices having a dielectric breakdown layer.

It is well known in the electroluminescent art that a higher voltage across an electroluminescent device will cause a brighter light to be generated thereby. A dielectric layer is required in such high voltage devices to prevent electrical breakdown thereacross which results in the destruction of the electroluminescent device. Aluminum oxide is known for use as such a breakdown layer.

It is, therefore, an object of this invention to provide a novel method of forming a dielectric breakdown layer in an electroluminescent device.

It is a further object of this invention to provide, in the anodization of an aluminum layer in a partially fabricated electroluminescent device, an indication of when it is desirable to terminate the anodization.

Briefly, these and other objects, which will become apparent as the description proceeds, are achieved by providing a method for forming an aluminum oxide breakdown layer over a partially completed electroluminescent device comprising a suitable substrate material, a film of conductive material forming a first or base electrode carried by the substrate, and an activated electroluminescent phosphor layer formed over the first electrode. In accordance with the present method, an aluminum metal layer is formed over the phosphor layer. The aluminum metal layer is substantially completely anodized into an aluminum oxide layer to form the breakdown layer by passing the anodizing current through the partially fabricated device. As the aluminum layer anodizes, the electrical resistance of the partially complete device increases. When the aluminum is substantially completely anodized to aluminum oxide, the resistance is substantially constant. That is, the measured resistance does not change with time. The point in time of complete conversion can be determined manually or automatically by simultaneously detecting and comparing the anodizing current and anodizing voltage. Properties of the aluminum metal layer other than the resistivity may be used in the determining when complete anodization has occurred. These other properties, such as light transmission, are dependent upon that amount of the original aluminum metal which is not anodized.

The present invention will become more apparent when considered in view of the following detailed description and drawings, in which:

FIGURE 1 is a pictorial view of the completed device;

FIG. 2 is a sectional pictorial view of a partially complete device during the constant current anodizing step of the present method;

FIG. 3 is a graph of the anodizing voltage against time, with the anodizing current held constant;

FIG. 4 is a graph of the anodizing current against time, with the anodizing voltage held constant; and

FIG. 5 is a pictorial view of the partially complete device during the anodizing step in which a light beam is used to aid in determining when the anodization is complete.

Referring now to FIG. 1, there is shown a complete electroluminescent device 10. A substrate material 12 is provided which is preferably made of glass. Ceramics may be employed which can withstand a firing temperature to be discussed below. A first electrode 14, preferably of tin

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oxide, is formed over the substrate 12. Other conductive materials may be employed in place of the tin oxide, provided they have suitable light transmission and conductive properties. A phosphor, layer 16, preferably of activated ZnS, is deposited over the first electrode 14. It is electrically desirable that the phosphor layer 16 be substantially continuous, and therefore film forming techniques such as vacuum deposition are preferred. As an example, the phosphor film 16 is two microns thick, but this thickness may vary considerably. The phosphor film 16 is activated, preferably by firing, for approximately one hour in the presence of suitable activators which for ZnS are, for example, copper and suitable halogen or trivalent metal such as aluminum. The firing temperature is between 700 and 800° C., 750° C. being preferred. The above-described method for activating an electroluminescent film is well known and is disclosed in more detail in U.S. Patent No. 3,044,902, dated July 17, 1962.

After activation of the phosphor film 16, an aluminum metal layer 17 (shown in FIGURE 2) is formed over the phosphor film 16 and converted into aluminum oxide to form the aluminum oxide dielectric layer 18. The conversion is accomplished by anodization and is described in detail in connection with FIG. 2. Referring again to FIG. 1, after the aluminum oxide layer 18 is formed, a thin electrically conducting layer 20 is formed thereover, preferably by vacuum deposition. It is well known in the art to use a conductive material such as aluminum for this cover or second electrode 20. As can be seen in FIGURE 1, the electrodes 14 and 20 are spaced in parallel fashion and an operating electric field is established thereacross by applying an operating potential across input conductors 22. The electric field causes the phosphor film 16 to electroluminesce.

Referring to FIG. 2, there is shown a partially completed device 10a. The aluminum metal layer 17 is being converted by anodization into the aluminum oxide layer 18a. As mentioned previously, the aluminum layer 17 is formed, preferably by vacuum deposition, over the phosphor film 16 after the activation step.

This invention is operable over a wide range of thicknesses for aluminum metal layer 17, which include from 0.01 μ to about 20 μ , 0.1–3 μ being preferred. The anodization is accomplished by exposing the aluminum layer 17 to an anodization-supporting electrolyte 24 contained in a suitable containing means 26. Tartaric acid or oxalic acid, for example, are employed as the electrolyte 24. As an example, a 5% molar solution is used. However, the acid concentration is not critical. Other known anodizing electrolytes may be employed instead of those specified above. An anodizing electrode 28 is positioned contacting the electrolyte 24, but not contacting the aluminum layer 17. An anodizing voltage or potential from a constant current source 30 is applied across the electrode 28 and the first electrode 14. A constant anodizing electric current flows through a conducting path formed by the partially complete device 10a. More specifically, the conducting path is formed by the electrolyte 24, the oxide film 18a which is being formed, the remaining aluminum layer 17, the phosphor film 16, and the first electrode 14. The formed aluminum oxide film 18 provides a dielectric breakdown layer for the electroluminescent device 10. DC anodizing voltages or potentials of from 50 to 1000 volts are preferred, the thickness of the aluminum oxide film formed being about 15 A. per volt. For breakdown protection of 200 volts, the final thickness of the oxide film, after complete conversion of aluminum layer 17, should be at least about 0.3 μ . Generally, an anodizing time of approximately ten minutes will be sufficient for most applications.

As the anodizing step progresses, the instantaneous impedance of the partially completed device 10a in-

creases because a greater and greater portion of the low resistance conductive aluminum layer 17 is converted to highly resistive insulative aluminum oxide layer 18. Changes in this instantaneous impedance can be detected by simultaneously measuring the increasing anodizing voltage and comparing it with the constant anodizing current. As the anodization approaches substantial completion, the impedances of the oxide film 18 approaches a substantially constant value, and the anodizing voltage approaches a constant value as shown in FIG. 3. The impedance change approaches zero. The constant impedance of the aluminum oxide film 18 may be electronically or manually detected and the anodizing voltage terminated.

If desired, the anodizing may be effected with a constant voltage, in which case the anodizing current decreases as the anodization proceeds. Complete anodization is then indicated by a leveling off of the anodizing current when the impedance of the oxide film 18 reaches a substantially constant maximum value. The curve of decreasing anodizing current against time is shown in FIG. 4. The flat portion of the curve indicates substantially complete anodization. A constant voltage method requires more time to complete the anodization because the anodizing current is decreasing.

The maximum anodizing voltage employed during the anodizing step should be sufficient to oxidize the aluminum metal completely through. This requires approximately 0.07 volts per angstrom of aluminum thickness. If the aluminum is not completely oxidized, a conductive film of aluminum will remain disposed between the phosphor film 16 and the aluminum oxide dielectric layer 18. It is preferable that the final anodizing voltage be slightly greater than calculated to be sure that the aluminum metal is completely anodized. Also, a higher anodizing voltage will speed up the anodizing process.

Referring to FIG. 5, there is shown an alternate method of determining when the aluminum metal layer 17 is completely anodized. A light source 32 and a light sensing device 34, such as a photocell, are shown disposed on opposite sides of the partially completed device 10a. The photocell 34 monitors the light beam from the light source 32. As the anodization step proceeds, the partially complete device becomes increasingly light transmissive because the aluminum layer 17 is opaque and the aluminum oxide layer 18a is light transmissive, as are layers 12, 14 and 16. This increased light transmission is detected by the light sensor 34. When the light transmission reaches a predetermined or constant value, the anodizing step is terminated.

It will be apparent to those skilled in the art that the objects of this invention have been achieved by providing a novel method of manufacturing an aluminum oxide breakdown layer for an electroluminescent device. The completion of the anodizing step can be determined by observing the anodizing voltage and current, at which time the anodizing voltage is removed. Further, the light transmitting properties of the partially complete device may be employed to indicate the completion of anodization.

Although the invention has been described with respect to preferred embodiments thereof, it is not to be

so limited as changes and modifications may be made therein which are within the intended scope of the invention.

What is claimed is:

1. The method of providing an aluminum oxide dielectric breakdown layer over a partially completed electroluminescent device, wherein said partially completed device comprises a first electrode carried by a substrate, and a substantially continuous electroluminescent phosphor layer disposed over said first electrode, said method comprising the steps of:
 - forming an aluminum metal layer over said phosphor layer;
 - exposing said aluminum metal layer to an anodizing-supporting electrolyte;
 - anodizing said aluminum metal layer by applying an anodizing potential across said electrolyte and said first electrode to cause an anodizing electric current to pass through said partially completed electroluminescent device and said aluminum metal layer; and
 - continuing to apply said potential across said electrolyte and said first electrode until said aluminum metal layer is substantially entirely converted to aluminum oxide.
2. The method as specified in claim 1, wherein after said aluminum metal layer is converted to aluminum oxide, an additional metal layer is formed over said aluminum oxide layer.
3. The method as specified in claim 1, wherein said aluminum metal layer is anodized by maintaining a substantially constant current through said partially completed device and said aluminum metal layer for a sufficient time to complete anodization of said aluminum metal layer.
4. The method as specified in claim 1, wherein said aluminum metal layer is anodized by maintaining a substantially constant potential across said first electrode and said electrolyte for a sufficient time to complete anodization of said aluminum metal layer.
5. The method as specified in claim 1, wherein a light beam is projected onto said partially completed device during anodization of said aluminum metal layer with the light transmission characteristics of said partially completed device monitored during anodization, and the process of anodization is terminated when the light-transmission characteristics of said partially completed device increase to a predetermined value.

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